Prosthetic Valves Evaluation Made Easy  By:  Jonathan D. Leff, M.D.

Objectives:
1. Understand the different types of prosthetic valves.
2. Understand the evaluation of the prosthetic valve following implantation.
3. Understand the complications associated with prosthetic valves.
4. Understanding prosthesis- patient mismatch.

Prosthetic valves have revolutionized the way we treat patients with valvular disease. Before the advent of these valves patient’s options were limited and morbidity and mortality high. In the early 1960’s valve replacement surgery was introduced which dramatically changed the management of these patients. Prosthetic valve technology continues to evolve and surgeons have multiple options to offer an individual patient. Approximately 90,000 valve prosthetics are implanted in the United States and 280,000 worldwide each year. Given the large number of prosthetic valves implanted, the anesthesiologist caring for these patients must understand all the options and how to evaluate the valves with ultrasound.

There are a number of commercially available valves on the market. They can be divided into two categories either mechanical or biological. Mechanical valves were the first available for surgical implantation and have the advantage of being highly durable. However, the mechanical valve is thrombogenic and requires lifelong anticoagulation with careful monitoring of bleeding levels. There are three basic types of mechanical valves: caged ball valves, bileaflet and monoleaflet. Caged ball valves consist of a silastic ball with a circular sewing ring and 3 metal arches. These valves are no longer implanted but might be encountered in patient’s presenting for re-operations. The caged ball valves have a high tendency to form clots and the patient’s INR needs to be maintained at 2.5-3.5. The caged ball valves are also limited by the need for the heart to work harder to push blood around the ball. Normal blood flow is through a central orifice, which is not possible with the caged ball prosthetic valve. Edwards Lifesciences discontinued this valve in 2007. In contrast to the caged ball mechanical valve the tilting
The single tilting disc consists of a single circular disc restrained by two metal struts and a metal ring. The single tilting disc can open at an angle of 60 degrees and a rate of 70 beats per minute. This is an improvement in central flow compared to the caged ball valve. However, the single tilting disc is prone to fatigue and fractures over longer periods. The bileaflet mechanical valve addresses some of the issues encountered with the single tilting valve and was introduced in 1978. This valve contains two semicircular leaflets, which pivot along hinges. These valves have the most central flow and therefore provide the least resistance to flow and the least blood cell damage. However, the bileaflet valves have considerable backflow, which can be problematic for some patients. The bileaflet valve is the most commonly implanted mechanical valve. Bioprosthetic valves are aimed at imitating native valve function and thus not requiring anticoagulation. The porcine bioprosthetic valve consists of 3 porcine aortic valve leaflets mounted on a metallic supporting stent. The porcine valves are limited in size whereas the bovine pericardial valves offer more options for sizing. The bovine pericardial valve is also supported by a stent. In contrast, stentless valves have absence of the frame thus creating larger orifice area for flow, improving hemodynamics and possibly promoting regression of LVH. These stentless valves are manufactured from either whole porcine aortic valves or bovine pericardium. There is growing interest in the percutaneous implantation of bioprosthetic valves. These sutureless valves offer an alternative for patients who are poor surgical candidates. The PARTNER I trial revealed an improvement in survival (20%) with the use of the percutaneous aortic valve insertion versus optimal medical management. More recently investigation revealed similar patient survival comparing transcatheter aortic valve replacement (TAVR) vs. high risk surgical aortic valve replacement. The percutaneous valves are normally inserted either by a transfemoral or transapical approach. These valves are trileaflet and affixed within a cage. Upon deployment the percutaneous valve expands to fit the annulus.

The use of echocardiography for the perioperative evaluation of prosthetic valves can be challenging. The valves have poor acoustic properties and the echocardiographer must overcome echo shadowing and dropout. The prosthetic valve should be interrogated with 2D imaging, color flow Doppler and spectral Doppler. Many of the valves will have
some degree of obstructive flow compared to native valves, but need to be investigated to determine pathologic versus normal flow pattern. The valves also have normal “physiologic” regurgitation, which has different characteristics depending on the prosthetic valve. For example, multiple “washing” jets are observed with a mechanical valve and serve to facilitate valve mechanics and wash the artificial surface to prevent the formation of thrombus. In contrast, small central jets are occasionally observed with bioprosthetic valves. It is therefore important to understand the unique features that each valve can present in order to differentiate pathologic features from normal function. The first aspect of echo interrogation is the appropriate documentation of type and size of the implanted valve. In addition, the patient’s height, weight, and BSA should be noted in order to assess prosthetic-patient mismatch (PPM). The prosthetic valve should be interrogated with transesophageal echo (TEE) in multiple views with comment on the opening and closing of the prosthetic valve. In addition, the appearance of the sewing ring should be examined for abnormal rocking movement or the presence of a perivalvular leak. For patients presenting with prosthetic valves attention to the existence of leaflet calcifications or abnormal echo densities around the valve should be noted. Color flow Doppler can be useful in distinguishing transvalvular from perivalvular leaks. The transvalvular gradients and velocities are assessed with spectral Doppler. All prosthetic valves have some degree of obstruction and the manufacturer provides normal gradients and velocities for each individual valve. In addition, transvalvular leaks are seen in all mechanical valves and a small percentage of bioprosthetic valves. The use of spectral Doppler tends to overestimate the valvular gradient especially with bileaflet mechanical valves in the aortic position. This phenomenon of higher transvalvular gradients with spectral Doppler compared with catheter derived gradients is thought to be secondary to pressure recovery. The concept is based on blood flow velocity being higher through the central orifice compared to the 2 semicircular orifices and therefore Doppler interrogation at this point will be higher using the Bernoulli equation. When the pressure is assessed more distal to the valve (as with catheter interrogation) a recovery of the pressure is observed thus providing lower overall gradients. In addition, the use of pressure half time (PHT) for calculation of mitral valve area (MVA=220/PHT) is relatively accurate with native stenotic mitral valves but may not be applicable to
prosthetic valves. A simple way to assess prosthetic valve function is to document the peak and mean transvalvular gradients and compare it to the manufacture normal values. The continuity equation can also be used to establish the valve area and compared with the manufacture values for a specific valve type and size. The issue with spectral Doppler for the postoperative evaluation of a prosthetic valve resides in the dynamic conditions present in the perioperative period. Doppler measurements are altered by flow which can be significantly different in the perioperative period compared with normal physiologic conditions. For example, a patient on inotropes with increased cardiac output will have higher transvalvular flow and thus increased prosthetic gradients. The use of the dimensionless index for assessment of prosthetic valves potentially overcomes some of the aforementioned limitations. The index flow compares either peak velocity (V) or velocity time integral (VTI) at the LVOT and across the prosthetic valve. In the aortic position an index ($V_{LVOT}/V_{AoV}$) less than 0.35 may indicate prosthetic valve stenosis.

The ability to understand the evaluation of prosthetic valves is critical for providing optimal care to patients undergoing valve replacement. The types of valves available and understanding the limitations of each prosthetic can alter patient management. There continues to be improvement in prosthetic valve technology with the goal of providing the optimal transvalvular flow, decreased thrombogenicity, increased durability and minimize hemolysis. Knowledge of a particular valve characteristic will allow the echocardiographer to distinguish between “normal” function versus a pathologic process (i.e. PPM). The documentation and transfer of information obtained from echocardiographic interrogation of a prosthetic valve to the surgical team has the potential to improve outcome and reduce the need for future intervention.

REFERENCES


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